# Laboratory Directed Research and Development Program
# Berkeley Lab FY 2003 Coversheet

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|---|---|---|
| **Project Title:** | **Concepts for a Premier Stable Beam Facility for Low Energy Nuclear Physics** | **Prop No.** |
| **Investigator(s):** | Daniela Leitner, I-Yang Lee, and Stuart Freedman | **Budget No.** |
| **Division: NSD** | | **PAO OFFICE USE ONLY** |

**Funds Requested (FY 2003): $278,509**

**Proposed Project Duration: 2 years** **Out Year Funds Requested: (for multiyear projects only)** $280,000

**New Proposal** [x] **Continuation** [ ]

**Long-Term Funding (amount, source, likelihood):**
15 M$ over several years, DOE Nuclear Physics, Very Probable

**Collaborating Divisions or Institutions:**
Eleanor Blakely, LSD


## Summary

**Purpose /Goals:**
Our goal is to initiate and develop the technical plan for creating a world-class stable ion beam accelerator to be sited at Lawrence Berkeley National Laboratory. The low energy nuclear physics community requires a state-of-the-art accelerator complex capable of accelerating essentially all elements, and providing high intensity light and heavy mass ion beams with precise timing capabilities. A world-class stable ion beam accelerator will be a key component of the future US nuclear physics program, whether or not the Rare Isotope Accelerator (RIA) is built. To be successful Berkeley must begin immediately to position itself as the national facility for stable beam research. The Gamma Ray Energy Tracking Array (GRETA) now under development and other advanced instrumentation at LBNL will help establish this facility as unique in the World. The ongoing development of advanced ECR (Electron Cyclotron Resonance) sources will ensure leadership in a critical supporting technology. LBNL's close connection to the UC campus, its strong established research programs in nuclear structure and reactions, heavy element chemistry, and weak interactions, make it the ideal site for the nation's premier stable beam accelerator complex.

**Approach/Methods:**
Our first task is to consider the most straightforward option by exploring the feasibility and cost effectiveness of a major reconstruction of the 88-Inch Cyclotron. Would this upgrade provide essential new accelerator capabilities for meeting the needs of the low energy nuclear physics community during the next decade?
The second task is to evaluate alternative concepts: a new cyclotron or perhaps a superconducting linac to be sited at the 88-Inch Cyclotron complex or another Berkeley Lab site. To be useful these must be detailed analyzes resulting in a list of parameters and requirements, conceptual beam optics and preliminary engineering layouts. The second year of the project is the critical phase of evaluating the results of the first year's research and refining the overall plan. A focused team of engineers, accelerator and nuclear physicists will address these issues. Input from the larger nuclear physics community would be sought with workshops and visits by experts.


**Relationship to other Berkeley Lab projects sponsored by DOE or other agencies:**
It will enhance current programs and provide new research opportunities in nuclear physics and biology.

**Will human subject data, cells, or tissues and/or animal be used on this project? If yes, fill in the Human/Vertebrate Animal Use form. (See instructions)** **Yes** [ ] **No** [x]

*On an attachment (3 pages, maximum), please pro vide a brief description of the project:* ***Purpose / Goals; Approach / Methods; potential results or significance*** *and, if multi-investigator or multi-divisional, proposed organization.*

# Concepts for a Premier Stable Beam Facility for Low Energy Nuclear Physics

## 1. Scientific Opportunities

The 2002 NSAC Long Range Plan (LRP) provides a compelling case for the exciting opportunities in low energy nuclear physics in the next decade and beyond. The LRP identified broad research areas of nuclear structure, nuclear astrophysics, and weak interaction studies as vital components of the US nuclear physics program. The community's strong endorsement of this science was reflected in the fact that RIA is the highest priority for new construction in the LRP and that GRETA, the next generation gamma-ray detector conceived and developed at LBNL, was identified as one of the major new instrument initiatives in nuclear physics[1]. In addition, a recent NSAC review of Low Energy Nuclear Physics clearly emphasized the importance of maintaining a strong research program in structure, astrophysics and weak interactions, endorsing the case for at least one world-class stable beam facility that will remain viable into the RIA area.

A world-class stable ion beam accelerator at LBNL will have an important role to play in the nation's future nuclear physics program - with or without RIA. GRETA at LBNL will make this facility unique, not only in the US but also worldwide. The ongoing development of advanced ECR sources ensures leadership in this critical area of modern accelerator development. The strong research programs at LBNL in nuclear structure and reactions, heavy element chemistry, and weak interactions, together with the close connection to campus, make Berkeley an ideal place to carry out this research and a logical choice for a premier stable beam facility.

Cutting edge experiments in low energy nuclear physics will require a next generation stable ion beam facility. The key aspects of such a facility are versatility, high quality beams and high intensities.

Exciting physics opportunities exist in nuclear structure requiring intense stable ion beams to produce and explore exotic nuclei. These nuclei exhibit interesting properties such as superconductivity and regular-to-chaos transitions, which has broad implications in other fields such as solid-state physics. Currently interesting questions in weak interaction studies are at the core of the Standard Model: What are the precise values of the quark mixing matrix elements? What is the mass of neutrinos? Do induced currents obey the symmetries demanded in the Standard Model? Can the patterns of discrete symmetry breaking, charge conjugation, parity and time reversal be described in the standard model? Nuclear weak interactions studies depend on intense stable beams to produce the copious activities needed for high-precision experiments involving trapping of radioactivity.

Opportunities to expand our knowledge of Astrophysics and Cosmology will also be enabled by the stable beam facility. To probe nuclear fusion reactions involved in stellar fuel cycles and solar neutrino production, the major limitation has been the lack of intense, high quality, low-energy stable beams. These experiments are complementary to studies with the relatively low intensity rare isotope beams that will be available at RIA. Without a palette of stable beam accelerators, we jeopardize our ability to mount crucial experiments in fundamental interactions or nuclear astrophysics that demand long periods of development and data accumulation. While a world-class rare isotope accelerator RIA will add enormously to our arsenal of experimental tools, the future must also include enhanced capabilities of stable beam facilities for an outstanding and balanced research program in these areas.

In addition, the development of a premier, stable beam facility at LBNL would provide opportunities for expansion of existing biomedical investigations to areas such as effects of low radiation doses encountered in the workplace on earth or in space[2]. Similarly, such a beam facility would be useful in testing and improving electronics for space-based applications and detectors for high energy physics experiments.

The 88-Inch Cyclotron, like its counterparts- ATLAS at ANL and the Holifield facility at ORNL- is approaching the end of its useful life, at least in its present configuration. Therefore, a new heavy ion facility will be needed to meet the physics demands into the next decade. It is critical that we begin the task of positioning Berkeley as the site for the premier stable beam facility now to ensure a leading role for Berkeley in the Nuclear Physics community.

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[1] RIA and GRETA, together with the CEBAF upgrade are the three projects for which DOE Nuclear Physics is attempting to obtain CD0 this year.

[2] in response to calls for proposals by combined government agencies (e.g., DOE/NASA Program Announcement LAB 02-15).

## 2. Proposed work

The goal of the present LDRD is to evaluate possible paths to a premier stable beam facility at Berkeley Laboratory, and write a proposal for a premier stable ion beam facility sited at LBNL. A small, focused team including accelerator physicists, nuclear physicists and engineers with expertise in vacuum technology and high power RF would be assembled and tasked with the job to complete this study. Three options will be studied:

### 2.1 Cyclotron Upgrade

The first option would be to evaluate the feasibility, cost effectiveness and desirability of reconstructing and upgrading the 88-Inch Cyclotron by replacing major subsystems that presently limit the capabilities of the accelerator and its life expectancy.
This approach would preserve the existing cyclotron iron yoke and magnet poles, but would aim to refurbish the main, trim, and valley magnet coils. The vacuum chamber, and the Dee stem would be redesigned and several external beam lines would be upgraded. Electrical upgrades would include a new RF system and possible ways to lower the resonance frequency of the cyclotron.
Magnetic modeling and beam dynamic studies must accompany those engineering studies to ensure proper reconstruction. This option would retain the present capabilities of the 88-Inch Cyclotron, but enhance the reliability and the performance in respect to ion beam intensity.
The main focus during the first year will be to develop a cost range and a time schedule for a cyclotron upgrade which minimizes the impact on the scientific program. For this purpose, two key issues need to be answered in the first year:

1) Determine the best approach to disassemble the 88-Inch Cyclotron vacuum and magnet system, reconstruct, and reassemble it.
2) Study ways to lower the frequency range of the cyclotron. This issue influences the cyclotron performance for high intensity beams around the Coulomb barrier and is therefore crucial for the comparison of the different options.

### 2.2 New Cyclotron facility

The second option would be to explore the advantages of a new cyclotron replacing the 88-Inch Cyclotron. The goal of this study is to develop a parameter and requirement list as needed by the scientific community, and develop a preliminary design layout and cost estimate. Existing facilities such as CIME at GANIL would be used as the design reference.

### 2.3 Superconducting Heavy Ion LINAC

The third option would be to explore concepts for a superconducting heavy-ion linac sited at Berkeley Lab. The goal of this study is to develop a parameter and requirement list as needed by the scientific community, identify the major components: LEBT (Low Energy Beam Transport), RFQ, cavity type, and overall LINAC length. A preliminary layout and cost estimate will be developed by the end of FY03. The RIA driver LINAC would be used as the design base.

## 3. Second year

In the critical, second year, the strengths and weaknesses of the three different approaches in terms of project scope and budget will be evaluated. The key issues are the new scientific opportunities in each scenario and the expressions of interest from the nuclear physics communities. We will also focus on turning this effort into a proposal to the DOE Nuclear Physics Program Office in close collaboration with the accelerator physics division. We expect that we will organize workshops and meetings to involve the broader nuclear physics community (nuclear scientists, accelerator physicists and engineers) in this phase of the project.

# 4. Major Milestones for the first year

<table>
<tr><td colspan="2">2.1 Cyclotron Upgrade</td></tr>
<tr><td>Tasks</td><td>Key Personnel</td></tr>
<tr><td>Redesign vacuum chamber</td><td rowspan="2">Mechanical Engineer TBD</td></tr>
<tr><td>Magnet system:<br>Main, trim, valley coils</td></tr>
<tr><td>Evaluate possibilities to lower the cyclotron resonance frequency</td><td>RF engineer TBD</td></tr>
<tr><td>Scheduling and planning</td><td rowspan="2">D. Leitner</td></tr>
<tr><td>Scientific support</td></tr>
<tr><td colspan="2">2.2 New Cyclotron Facility Study</td></tr>
<tr><td>Parameter study and evaluation of existing facilities (CIME cyclotron, GANIL)</td><td>D. Leitner, Postdoc TBD</td></tr>
<tr><td>Preliminary Layout</td><td rowspan="2">D. Leitner</td></tr>
<tr><td>Cost estimate</td></tr>
<tr><td colspan="2">2.3 Superconducting Heavy Ion Linac Study</td></tr>
<tr><td>Parameter study and evaluation of suitable designs (RIA driver accelerator)</td><td rowspan="4">M. Leitner, Postdoc</td></tr>
<tr><td>Identify mayor components<br>LEBT, RFQ, Superconducting Cavities</td></tr>
<tr><td>Preliminary Layout</td></tr>
<tr><td>Cost estimate</td></tr>
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# 5. Budget

See attached spread sheet.